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Ecological indicator role of butterflies in Tam Dao National Park, Vietnam

Роль бабочек как экологических индикаторов в национальном парке Там Дао (Вьетнам)

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КЛЮЧЕВЫЕ СЛОВА: бабочки, семейства, роды, виды, экологически индикаторы, леса, местообитания, Вьетнам

ABSTRACT. Ecological indicator role of butterflies was assessed in Tam Dao National Park, Vietnam from May to October over three years from 2002 to 2004. The transect method was used to collect data. Thirty transects representing five different habitat types were set up at the altitude of 900–950 m a.s.l., from the natural closed forest to the agricultural land, with a length of 100 m for each transect. Indicator values were quantified for each butterfly family, genus, and species. The results showed no any butterfly family could be used as ecological indicator for the natural closed forest. Among many genera and species of butterflies recorded along thirty transects, only three butterfly genera and three butterfly species can be used as ecological indicators to assess the impact of disturbance on the natural closed forest. Genus indicators are *Ragadia, Neope, Stichophthalma*; species indicators are *Ragadia crisilda, Neope muirheadi,* and *Stichophthalma howqua*. Satyridae and Amathusiidae are characteristic butterfly families for the forest, but they are only can be used as ecological indicators for forest in general (the habitat inside forests, including the natural forest and the disturbed forest), not for natural forest. Although butterflies are sensitive to forest disturbance, very few butterfly species can be used as ecological indicators to assess the impact of disturbance on the natural closed forest.

РЕЗЮМЕ. На основании трёхлетних сборов с мая по октябрь 2002–2004 гг. проведена оценка роли бабочек как экологических индикаторов в условиях национального парка Там Дао (Вьетнам). Для сбора материала использовался метод трансект. В пяти типах местообитаний на высоте 900–950 м было заложено 30 трансект длиной 100 м от естественного сомкнутого леса до агроландшафтов. Для каждого семейства, рода и вида бабочек были определены количественные показатели индикации. Установлено, что ни одно из семейств чешуекрылых не может быть использовано в качестве индикатора естественных сомкнутых лесов. Из всего многообразия бабочек, отмеченных на тридцати трансектах, только три рода и три вида могут быть использованы в качестве индикаторов для оценки нарушенности естественного сомкнутого леса. Это роды *Ragadia*, *Neope*, *Stichophthalma* и виды *Ragadia crisilda*, *Neope muirheadi* и *Stichophthalma howqua*. Такие характерные лесные семейства как Satyridae и Amathusiidae могут быть использованы в качестве экологических индикаторов для лесов в целом (как ненарушенных, так и нарушенных), но не для естественных. Не смотря на то, что бабочки чутко реагируют на нарушения лесного сообщества, лишь немногие виды могут быть использован в качестве экологических индикаторов для его оценки, особенно в естественном сомкнутом лесу.

Introduction

Ecological disturbance is a frequent and important process in tropical forest ecosystems, especially in developing countries such as Southeast Asia. Tropical forest communities have changed in composition and abundance over time due to forest succession, weather conditions as well as habitat fragmentation and disturbance [Erhardt, 1985; Lawton et al., 1998; Debinski et al., 2000; Summerville & Crist, 2001; Kruess & Tscharntke, 2002]. Butterfly fauna is usually associated with its corresponding vegetation types. Although many butterfly larvae feed on a variety of plants, a small number of butterfly larvae feed on only a single plant. Forest disturbance obviously causes changes in vegetation types that consequently affect butterfly fauna. Any changes in the forest can lead to changes in butterfly communities because they are highly sensitive to changes in habitat disturbance or habitat quality [Collinge et al., 2003; Shahabuddin & Terborgh, 1999; Spitzer et al, 1997; Vu & Yuan, 2003]. The response of butterfly

communities to habitat changes is probably one of the most conspicuous; moreover, the butterflies are observed easily and the species are better known than most other groups of insects making them good subjects of study.

Assessing the environmental impact on plants and animals is usually difficult and expensive. One rather easy and cheap way to monitor and assess environmental impacts on animals and plants is to use indicator species. Identifying and developing eco-indicators is considerably recent among ecologists and biologists in conservation of biodiversity. Attention has focused on the use of terrestrial invertebrates as bio-indicators because of their dominant biomass and diversity and their fundamental importance in ecosystem function [Disney, 1986; Rosenberg et al., 1986; Majer 1989]. Indicators have been used to assess ecosystem responses to environmental disturbance that are often associated with human land use [Noss, 1990; Mc Kenzie et al., 1995]. Indicators are also used to assess rapidly the environmental status under stresses of human activity [McKenzie et al., 1995; Noss, 1990].

Effect of environmental changes to backboned animals usually takes a long time to realize [Struhsaker, 1997] and is difficult to detect compared to invertebrates [Murphy & Wilcox, 1986]. Certain groups, such as butterflies, which are known to include many species dependent on forest [Collins & Morris, 1985], are better choices than others [Kremen, 1992]. It is suitable to use butterflies as eco-indicators of forest disturbance because they are sensitive and quickly react to changes of habitat and environment, fly during the day, are rather diverse and in relative abundance, and have short generation times. Among insects, butterflies that are sensitive to habitat change are widely recognized as potentially valuable ecological indicators [Brown, 1991; Erhardt, 1985; Gilbert, 1984; Kremen, 1992; Kerr et al., 2000; Sparrow et al., 1994; Sutton & Collins,1991].

Although butterflies are widely recognized as good eco-indicators, there is limited research work to define butterflies which can be used as indicators to monitor and assess the impact of human being on tropical forest systems. This paper presents the result of study to define butterflies as eco-indicators of the tropical forest of Tam Dao National Park, Vietnam in family, genus and species levels. This is perhaps the first work to define different ecological indicator taxa of butterflies in tropical forests of Southeast Asia.

Research methodology

Research site

Research was carried out in Tam Dao National Park, Vietnam (21°21'–21°42' North and 105°23'–105°44' East). The park consists of 36.883ha of natural forest and 15.515ha of buffer zone. The forest is evergreen tropical rain forest. The study was carried out on mountains at an altitude of 900–950 m a.s.l.

Thirty transects representing five different habitat types were chosen, with a length of 100 m for each transect. Transects are separated from each other by least 50 m. The vegetation of the five habitat types in the study is summarized below, with the identification and nomenclature of vegetation following Pham [1999–2000].

Natural closed forest (S1): closed forest with a variety of plant species with diameter from 10–50 cm, canopy height of 8–15 m. Main plant species are *Castanopsis fissa*, *C. hytrix*, *C. cerebrina Quercus bambusaefolia* (Fagaceae); *Litsea afglutinosa*, *L. baviensis*, *L. lencilimba*, *L. verticillata*, *Machilus grandifolia* (Lauraceae); *Asarum maximum* (Aristolochiaceae); *Bridelia monoica* (Euphorbiaceae); *Sapium discolor*, *Musaenda dehiscen, Anthocephalus indicus*, *Wendlandia paniculata* (Rubiaceae); *Mallotus cochinchinesis* (Euphorbiaceae); *Manglietia hainamensis*, *Manglonia sp.* (Magnoliacea); *Scheffera octophylla* (Araliaceae); *Camellia pubicosta*, *C. rubiflora*, *C. caudata* (Theaceae); *Cylindrokelupha* sp. (Mimosaceae); *Gironniera subacqualis* (Ulmaceae) and *Acer wilson* (Araceae).

Disturbed forest (S2): canopy height of 5–10 m with shrubs and small to medium trees and bamboo. Main species are *Castanopsis fissa*, *C. hytrix*, *Quercus bambusaefolia* (Fagaceae); *Manglonia sp.* (Magnoliaceae); *Musaenda dehiscens*, *Wendlandia paniculata*, *Anthocephalus indicus* (Rubiaceae); *Melastoma spp.* (Melastomaceae); *Pygeum arboretum*, *Rubus alaefolius* (Rosaceae); *Ficus* sp., *F. vulga* (Moraceae); *Litsea baviensis*, *L. lencilimba*, *L. verticillata*, *Machilus grandifolia*, *Cariodaphnopsis tonkinensis*, *Cinnamomun tonkinensis* (Lauraceae); *Camelia sp.* (Theaceae); *Mallotus cochinchinensis, M. barbatus, Sapium discolor, Macaranca denticulata* (Euphorbiaceae); *Musa cocinea* (Musaceae); *Rubus alaefolius* (Rosaceae); *Acer wilson* (Aceraceae); *Indosasa crassiflora* and *I. hispida* (Bambusoidae).

Forest edge (S3): vegetation consists of small trees, shrub and grass. Main vegetation species are *Litsea lencilimba*, *L. verticillata*, *L. baviensis*, *L. cubeba, Cinnamomum iners*, *Actnophne pilosa* (Lauracaeae); *Imperata cylindryca*, *Centotheca lappaceae*, *Eagross unionoides*, *Thysanolea maxiam* (Poaceae); *Ageratum conyzoides*, *Artemisia vulgaris, Xanthium strumarium;* and other small plant species of Fagaceae, Magnoliaceae, Moraceae, Rosaceae, and Rutaceae.

Shrub and grass (S4): some shrubs with height of 20–50 cm and tall grass with height of 100–200 cm. The main grass species are *Euphobia thymifolia*, *Centotheca* sp., *C. lappaceae*, *Eagross unionoides*, *Imperata cylindryca*, *Saccharum arundidinaceumi* (Poaceae); *Melastoma normale* (Melastomacaea) and other shrub species of Lauraceae, Theaceae, Rosaceae, Fagaceae, Araliaceae and Sapindaceae.

Grass and agricultural land (S5): short grass with height of 10–50 cm and agricultural plants. Main plants are *Sechium edule*, *Saccharum arundidinaceum*, *Imperata cylindryca*, *Thysannolena maxima*, *Melastoma tomentosa*, *M. cnadium*, *Centotheca* sp., *Rubus alaefolius*, *Dahlia pinnata*, *Ipomoea blatas*, *Ageratum conyzoides*, *Dichrocephala* spp., and *Eleusine indica*.

Forests have been disturbed as a consequence of selective logging, bamboo shoot taking and other activities in the past as well as present time.

Sampling method

The butterfly transect methodologies which were used, were developed in England by Pollard [1977], and Pollard et al. [1975] for monitoring changes in a butterfly population (of a single species) over time and studying differences in the butterfly communities of different habitat types. This method was used in Vietnam [Spitzer et al., 1997; Vu & Yuan, 2003].

Transect work took place during 9:00am to 4:00pm. It took 6–8 minutes for each 100 m transect. The times for each transect were altered from day to day to reduce the effect of different times of day on recorded data. The recorders walked at a uniform pace and recorded all butterflies seen within prescribed limits in an imaginary box about 10 m × 10 m × 10 m. The transects were restricted to roads and paths, the boundaries of which were generally obvious.

The study was carried out from May to October over three years from 2002 to 2004. The study period lasted 5 to 7 days a month.

Butterfly habitats were divided into five habitat types as described above; in addition, habitat types were grouped into three habitat types that are the habitat inside forests (three transects of the natural forest and three transects of the disturbed forest), the habitat along forest edge (six transects), and the habitat outside forests (three transects of shrub and grass habitat, and three transects of agricultural land).

Identification and nomenclature of butterflies follows Chou [1994] and D'Abrera [1982–86].

Indicator values of butterflies

The indicator values of butterflies were calculated for the five and the three habitat types. A method used to quantify the "indicator value" of a range of taxa is the indicator value (*IndVal)* method developed by Dufrêne & Legendre [1997]. This method combines measurements of the degree of specificity of a species to an ecological state, for example a habitat type, and its fidelity within that state [Dufrêne & Legendre, 1997]. Species with high specificity and high fidelity within a habitat will have a high indicator value. High fidelity (frequency of occurrence) of a species across sample sites is generally associated with large abundance of individuals [Brown, 1984; Gaston et al,. 1997]. Both these characteristics facilitate sampling and monitoring, which is an important requirement for a useful indicator [Kremen et al., 1994].

The *IndVal* method has numerous advantages over other measures used for ecological indicator [McGeoch & Chown, 1998].

The individual numbers of each species recorded during the course of the study period (2002–2004) were summed for each habitat type. The indicator value method is used to study whether an individual butterfly species would show indicator value for any of the five or three habitat types. An indicator value for each species *i* in each group *j* of sites was calculated according to Dufrêne & Legendre [1997]:

$IndVal_{ij} = A_{ij} \times B_{ij} \times 100$, where

IndVal — indicator value for species *i* in group *j*,
A_{ij} is specificity measure as:

$A_{ij} = N\ individuals_{ij}/Nindividuals_i$ and where

$Nindividuals_{ij}$ — individual number of species *i* in 6 transects of habitat *j*,
$Nindividuals_i$ — total individual number of species *i* in 30 or 18 transects (each habitat type consists of 6 butterfly transects).
B_{ij} is fidelity measure as:

$B_{ij} = Nsites_{ij}/Nsites_j$ and where

$Nsites_{ij}$ — number of transects of habitat *j* as species *i* present,
$Nsites_j$ — total number of transects (6 butterfly transects) of that habitat.

Percentage indicator value was measured for each butterfly taxa from species to family. Species with indicator value of greater than 70% [McGeoch et al., 2002] are regarded as characteristic indicator species for the habitat. Species with *IndVal*s from 50–70% are regarded as detector species [McGeoch, 1998].

Results

Indicator values of butterfly famlies in five habitat types

To assess the indicator role of butterfly families for different habitat types, indicator value was calculated for each family. Table 1 shows that almost all butterfly families have low indicator values (less than 50%) in all

Table 1. Indicator values (%) of Lepidoptera families in five different habitat types.
Таблица 1. Количественные показатели индикации (%) семейств Lepidoptera в пяти различных местообитаниях.

Butterfly families	Habitat types				
	S1	S2	S3	S4	S5
Amathusiidae	57.43	22.77	15.84	3.95	0
Satyridae	53.78	29.63	5.58	9.87	1.43
Riodinidae	14.73	3.16	49.47	26.32	6.32
Nymphalidae	5.29	13.04	37.80	26.30	17.56
Lyceanidae	5.34	13.35	35.01	25.01	11.28
Danaidae	3.00	5.31	57.09	15.94	18.65
Papilionidae	2.30	17.56	43.04	16.92	32.11
Pieridae	1.67	22.18	41.54	25.89	25.30
Hesperiidae	1.34	9.29	31.00	27.97	30.38

Note: S1 — natural closed forest; S2 — disturbed forest; S3 — forest edge; S4 — shrub and grass; S5 — agricultural land.
Примечания: S1 — естественный сомкнутый лес; S2 — нарушенный лес; S3 — край леса; S4 — кустарники и трава; S5 — агроландшафт.

habitat types. Only three families have indicator value greater than 50%, of which two families are in the natural closed forest (S1) (Amathusiidae and Satyridae), and one family is in the forest edge (S3) (Danaidae). Indicator values of butterfly families (except families Satyridae, Amathusiidae, and Riodinidae) are lowest in the natural closed forest (S1), higher in the disturbed forest (S2) and highest in the forest edge (S3). They are lower in the shrub habitat (S4) and agricutural habitat (S5). Riodinidae family also has the highest indicator value in the forest edge. Families Satyridae and Amathusiidae have the highest indicator values in the natural closed forest and decrease with increasing forest disturbance (from the natural forest to the agricultural land).

No butterfly families can be used as eco-indicators for habitats that are divided into small scales of disturbance (the five different habitat types). Families Satyridae and Amathusiidae are characteristic for the natural closed forest; and family Danaidae is characteristic for the forest edge. These three butterfly families have indicator values greater than 50% but less than 70% so they can be only used as detector taxa for the natural forest and the forest edge.

Indicator values of butterfly genera in five habitat types

Using indicator taxa at the family level has some advantages because the taxonomy is simple, easy for monitoring. Nevertheless, not all species in the family have the same habitat preference, for instance, species of *Ypthima* genus (Satyridae family) usually live in disturbed forests or shrub and grass lands, and thus, indicator value of the whole family is not high. Another taxa level is genus. Indicator value of genus enables the researchers to identify indicator taxa more specific than family level; in addition, the advantage of genus is to reduce limitation of taxonomy of some difficult species in the field, such as species of genera *Ypthima* and *Mycalesis* (Satyridae family).

Indicator value of some butterfly genera (genera with indicator values greater than 50%) in five different habitat types is presented in Table 2. In the natural forest (S1), the genera with indicator values greater than 70% that can be used as eco-indicators for this habitat are *Ragadia*, *Neope*, and *Stichophthalma*. The genera with indicator values from 50–70% that can be used as detector genera for the natural forest are *Mycalesis* and *Mandarina*. In the forest edge (S3), all four genera of Danaidae family that can be used as detector genera of the forest edge are *Euploea, Parantica, Tirumala*, and *Ideopsis*. The other genus of Nymhalidae family that can also be used as detector of the forest edge that is *Stibochiona.*

Indicator values of butterfly species in five habitat types

More specific than genus and family levels is species level; the indicator value of species is taxa that are used the most frequently in identifying indicator species [Dufrêne & Legendre, 1997]. The advantage of indicator taxa at the species level is simple, easy to use and monitor, and highly accurate. However, identification of indicator species in the field is sometimes difficult, especially for species difficult to identify.

Indicator values of species in five different habitat types are presented in Table 3. Almost all species have indicator values less than 50%. Among 173 species recorded along five habitat types, there are only nine species with indicator values from 50–70%, of which two species are in the natural forest (S1) (*Mycalesis misenus, Mandarinia regalis*), one species is in the disturbed forest (S2) (*Ypthima imitans*), one species is

Table 2. Indicator values (%) of Lepidoptera genera in five different habitat types.
Таблица 2. Количественные показатели индикации (%) родов Lepidoptera в пяти различных местообитаниях.

Butterfly genera	Habitat types				
	S1	S2	S3	S4	S5
Ragadia	72.16	36.33	1.67	0.37	0
Neope	71.63	16.67	1.98	4.94	0
Stichophthalma	70.06	19.12	7.96	2.55	0
Mycalesis	58.60	30.09	4.98	6.34	0
Mandarina	51.85	25.19	0	0	0
Stibochiona	13.92	25.95	53.16	1.27	3.80
Parantica	7.02	6.06	64.01	7.95	14.67
Euploea	4.02	6.36	56.36	18.31	16.07
Tirumala	1.63	2.00	65.10	14.98	22.48
Ideopsis	0.81	2.85	55.28	19.92	11.65

Note as for Table 1.
Примечания как к Таблице 1.

Table 3. Indicator values (%) of Lepidoptera species in five different habitat types.
Таблица 3. Количественные показатели индикации (%) видов Lepidoptera в пяти различных местообитаниях.

Butterfly species	Habitats types				
	S1	S2	S3	S4	S5
Ragadia crisilda	72.16	36.33	1.67	0.37	0
Neope muirheadi	71.63	14.89	0.85	3.78	0
Stichophthalma howqua	70.06	19.12	7.96	2.55	0
Mycalesis misenus	60.62	30.05	3.89	5.44	0
Mandarinia regalis	51.85	25.19	0	0	0
Ypthima imitans	3.18	68.75	0	23.81	0
Tirumala septentrionis	0.34	1.58	60.14	14.19	22.30
Zemeros flegyas	0	0.27	58.06	30.65	9.68
Euploea mulciber	4.16	6.18	56.24	17.48	15.93
Ideopsis similis	0.81	2.85	55.28	19.92	11.65
Stibochiona nicea	13.92	25.95	53.16	1.27	3.80
Astictopterus jama	0	11.69	13.53	55.72	2.65

Note as for Table 1.
Примечания как к Таблице 1.

in shrub and grass habitat (S4) (*Astictopterus jama*), and five species are in the forest edge (S3) (*Tirumala septentrionis, Euploea mulciber, Ideopsis similis, Stibochiona nicea,* and *Zemeros flegyas.* There are three species with indicator values greater than 70% that can be used as eco-indicators for the natural forest, they are *Ragadia crisilda, Neope muirheadi*, and *Stichophthalma howqua*. In the shrub and grass habitat (S4), and agricultural land (S5), all species have indicator values less than 50%. In the previous research work, Spitzer et al. [1997] and Vu & Yuan [2003] also mentioned that *Ragadia crisilda* and *Stichophthalma howqua* can be used as eco-indicator species for the closed forest of Tam Dao.

There are differences in butterfly abundance of indicator species between five different habitat types. The result of one-way analysis (ANOVA) indicated the significant differences in butterfly abundance of indicator species between habitat types: *R. crisilda* ($F_{4,289} = 22.75$; $p < 0.001$), *N. muirheadi* ($F_{4,255} = 3.89$; $p < 0.01$), and *S. howqua* ($F_{4,289} = 13.20$; $p < 0.001$). Otherwise, there are not significant differences in butterfly abundance of indicator species between transects of the natural forest habitat: *R. crisilda* ($F_{5,434} = 0.89$; $p > 0.50$), *N. muirheadi* ($F_{5,383} = 0.90$; $p > 0.50$), and *S. howqua* ($F_{5,285} = 1.10$; $p > 0.30$). These three butterfly species can be confidently used as eco-indicators of the natural forest of Tam Dao Mountain.

Indicator values of butterfly families in three habitat types

Indicator value of butterfly families in three different habitat types is presented in Table 4. As in the five habitat types, butterfly families have the highest indicator values in the forest edge (except Amathusiidae and Satyridae), the lowest in the habitat inside forests. The families Satyridae and Amathusiidae differ from other families. They have the highest indicator values (greater than 70%) in the habitat inside forest, lower in the forest edge, and lowest in the habitat outside forests. Satyridae and Amathusiidae are very characteristic for habitats inside the forest and can be used as eco-indicators of this habitat. Butterfly families that have indicator values from 50–70% are Danaidae in the forest edge, and Hesperiidae and Pieridae in the habitat outside forests. These three butterfly families are characteristic for the forest edge and the habitat outside forests respectively. However, butterfly families have indicator values less than 70% so they are not used as indicator species, but as detector species of these habitat types.

Table 4. Indicator values (%) of Lepidoptera families in three different habitat types.
Таблица 4. Количественные показатели индикации (%) семейств Lepidoptera в трёх различных местообитаниях.

Butterfly families	Habitat types		
	Inside forest	Forest edge	Outside forest
Amathusiidae	80.20	12.67	3.17
Satyridae	76.26	11.50	12.23
Riodinidae	20.00	42.35	37.85
Lycaenidae	18.69	37.09	44.21
Nymphalidae	18.47	38.42	43.11
Danaidae	11.13	52.70	36.17
Hesperiidae	10.79	31.40	57.81
Pieridae	7.19	41.92	50.90
Papilionidae	8.05	46.54	45.41

Indicator values of butterfly genera in three habitat types

Indicator values of some butterfly genera with indicator values greater than 50% in three different habitat types are presented in Table 5. There are six butterfly genera with indicator values greater than 70% which are *Ragadia, Neope, Mandarinia*, *Mycalesis*, *Stichophthalma,* and *Thaumantis.* They all belong to families Satryridae and Amathusiidae. Three genera of Satyridae family have indicator values less than 70% and greater than 50% which are *Neorina, Lethe*, and *Melanitis.* Six butterfly genera with indicator values greater than 50% and less than 70% in the forest edge are

Table 5. Indicator values (%) of Lepidoptera genera in three different habitat types.
Таблица 5. Количественные показатели индикации (%) родов Lepidoptera в трёх различных местообитаниях.

Butterfly genera	Habitat types		
	Inside forest	Forest edge	Outside forest
Ragadia	94.07	4.48	0.20
Neope	85.80	8.78	5.41
Mandarinia	83.33	0	0
Stichophthalma	80.25	7.96	1.27
Mycalesis	79.60	14.02	6.33
Thaumantis	71.67	0	0
Neorina	66.67	0	0
Lethe	61.20	16.18	22.62
Melanitis	57.21	16.58	19.07
Euploea	10.60	55.69	33.71
Tirumala	8.80	53.74	37.45
Stibochiona	39.87	53.16	5.80
Ideopsis	10.94	53.13	29.95
Zemeros	0.32	51.08	47.00
Parantica	13.84	51.00	36.16
Pelopidas	0.06	31.22	63.33
Parnara	0.01	35.12	63.78
Argyreus	0	37.92	62.08
Zizeeria	0.39	42.97	54.69

Euploea, Parantica, Ideopsis, and *Tirumala* (Danaidae), *Stibochiona* (Nymphalidae), and *Zemeros* (Riodinidae). In the habitat outside forests, four butterfly genera with indicator values less than 70% and greater than 50% are *Parnara* and *Pelopidas* (Hesperiidae), *Argyreus* (Nymphalidae), and *Zireeria* (Lycaenidae).

Indicator values of butterfly species in three habitat types

Indicator values of butterfly species with value greater than 50% in three different habitat types are presented in Table 6. All butterfly species with indicator values greater than 70% in the habitat inside forests belong to families of Satyridae and Amathusiidae; they are *Ragadia crisilda, Neope muirheadi, Mandarinia regalis, Mycalesis misenus, M. inopia*, *Stichophthalma howqua*, and *Thaumantis diores*. There are seven species with indicator value greater than 50% and less than 70% in the habitat inside forests, which are *Neope bradha, Neorina patria, Lethe syrcis, Melanitis leda, Ypthima imitans* and *Lethe insana* (Satyridae), and *Enispe euthymius* (Amathusiidae). There are five species with indicator value greater than 50% and less than 70% in the forest edge which are *Euploea mulciber, Tirumala septentrionis, Ideopsis similis* (Danaidae), *Stibociana nicea* (Nymphalidae), and *Zemeros flegyas* (Rodinidae). In the habitat ouside forests, nine species with indicator value less than 70% and greater than 50% are *Astictopterus jama, Parnara apostata, P. guttata, P. bada,* and *Pelopidas* sp. (Hesperiidae), *Eurema hecabe* and *Pieris canidia* (Pieridae), *Stibochiona nicea* (Nymphalidae), and *Zizeeria maha* (Lycaenidae).

All butterfly species, which can be used as eco-indicators for habitats inside forests, belong to the families Satyridae and Amathusiidae. Among six butterfly species with indicator values greater than 50% and less than 70% in the forest edge, three of them belong to the Danaidae family. Among the nine butterfly species with indicator values greater than 50% and less than 70%, five species belong to the Hesperiidae family and two species belong to the Pieridae family. The Danaidae family are characteristic of the forest edge, and Hesperiidae and Pieridae are characteristic of the grass and agricultural land. Families Satyridae and Amathusiidae are very characteristic for the forest habitat and are good eco-indicators for monitoring changes of tropical forests. This result corresponds to the result of Keith & Brown [1997]. Among insect groups, the Satyridae family has very high indicator value that can be used to monitor the changes of tropical forest environments.

Indicator species should be easily observed and identified, if difficult to identify they can be only monitored by specialists and entomologists. In general, butterfly species, which can be used as eco-indicators in this study, have large wingspans and relatively easy identification in the field, especially *S. howqua* and *T. diores* (Amathusiidae). Species *R. crisilda*, the wingspan is not large but the species is one of the most common butterflies in the forest of the studied area, and its appearance differed from other species. Only two species *M. misenus* and *M. inopia,* as well as other species of *Mycalesis* genus, are relatively difficult for identification in the field. Nevertheless, *M. misenus* is very common and has a large wingspan compared to other species of *Mycalesis* genus in Tam Dao. Species *Mycalesis inopia*, although their wingspans are smaller than *Mycalesis misenus*, are easily distinguished from other species of *Mycalesis* genus. In general, butterflies used as eco-indicator species in this study are relatively easy to identify so they can be used for monitoring rather easily.

Table 6. Indicator value of Lepidoptera species (%) in three different habitat types.
Таблица 6. Количественные показатели индикации (%) видов Lepidoptera в трёх различных местообитаниях.

Butterfly species	Habitat types		
	Inside forest	Forest edge	Outside forest
Ragadia crisilda	94.07	4.48	0.19
Neope muirheadi	85.11	3.07	1.89
Mandarinia regalis	83.33	0	0
Mycalesis misenus	80.31	14.25	2.72
Stichophthalma howqua	80.25	7.96	1.27
Mycalesis inopia	76.58	0	2.70
Thaumantis diores	71.67	0	0
Neope bradha	66.67	0	0
Neorina patria	66.67	0	0
Lethe syrcis	61.48	15.85	18.90
Melanitis leda	57.21	16.58	19.07
Enispe euthymius	56.00	1.33	1.33
Ypthima imitans	50.79	0	11.90
Lethe insana	50.00	0	0
Euploea mulciber	20.69	58.04	33.41
Tirumala septentrionis	8.45	55.07	36.49
Ideopsis similis	10.94	53.13	29.95
Stibochiona nicea	39.87	53.16	5.80
Zemeros flegyas	0.32	51.08	47.00
Parnara apostata	0.56	35.40	63.49
Argyreus hyperbius	0	37.92	62.08
Pelopidas sp.	3.21	32.05	61.54
Eurema hecabe	0	17.78	61.11
Astictopterus jama	11.69	14.10	59.70
Zizeeria maha	0.40	42.97	54.69
Pieris canidia	0.68	48.57	50.61
Parnara guttata	0	0	50.00
Parnara bada	0	0	50.00

Conclusions

Butterflies are sensitive to forest disturbance, although, there is not any butterfly family that can be used as ecological indicator to assess impact of disturbance on the natural forest. Satyridae and Amathusiidae are the most characteristic families for the natural forest but not all species live in the natural forest. Some species of these families only live in the disturbed forest or other habitats. These species made indicator values of these families not high, but still greater than 50%. Indicator values of other butterfly families are very low in the natural forest (less than 15%). At the genus level, only three butterfly genera are very characteristic for the natural forest, with high indicator vales greater than 70%, can be used as ecological indicators of the natural forest, they are *Ragadia, Neope,* and *Stichophthalma.* At the species level, among 173 species recorded along transects, only three butterfly species with indicator values greater than 70%, can be used as ecological indicators for the natural forest, they are *Ragadia crisilda, Neope muirheadi,* and *Stichophthalma howqua.* These indicator genera or species can be used to assess impact of disturbance as well as other human activity on the natural forest. As other authors indicated that indicator species can be used to assess ecosystem responses to environmental disturbance that are often associated with human land use [Noss, 1990; Mc Kenzie et al., 1995].

There is not any butterfly family can be used as ecological indicator for any of five habitat types; nevertheless, at division of three habitat types (the habitat inside forest, the forest edge, and the habitat outside forest), Satyridae and Amathusiidae families are very characteristic for the habitat inside forest, with indicator values greater than 70%, can be used as ecological indicators for this habitat. A research of Bobo et al. [2006] indicated that the abundance of butterfly spcies with small range of distribution, especially spcies of Satyridae and Amathusiidae families are good indicators to assess and monitor disturbance on forest. More butterfly genera and species with indicator values greater than 70% can be used as ecological indicators of the habitat inside the forest. The indicator genera are *Ragadia, Neope, Mandarinia, Mycalesis, Stichophthalma,* and *Thaumantis*; the indicator species are *R. crisilda, N. muirheadi, Mandarinia regalis, Mycalesis misenus, M. inopia*, *S. howqua,* and *T. diores*.

Butterflies are flyers. They can fly from the natural forest to the distubed forest or the forest egde. It does not matter with many butterfly species whether they live in the natural forest or in the disturbed forest. Nevertheless, for some butterfly species, they are very sensitive to even light disturbance of the natural forest. This kind of butterflies are very good indicators for the natural forest. Butterfly species live in habitats outside forest such as forest edge, shrub and grass, and agricultural land are widely distributed so that can live in a variety of habitat types, not characteristic to any particular habitat type. This kind of butterflies are not indicators for habitats.

It is the best to use indicator species of the natural forest to monitor and assess impact of disturbance as well as other human activity on the natural forest. However, the use of indicator species in assessing the forest status need to base on individual density or abundance of indicator species in particular time and scale. This can be a threshold, below the threshold, the natural forest may be disturbed. The threshold or individual density of each indicator species are presented in Table 7. Below the individual densities of indicator species in the Table 7, the natural forest may be disturbed. Individual densities of different species are differed. Because butterflies fluctuate strongly overtimes. The individual densities of species are also different from month to month of the year. Their populations are high in some months but very low in the other months, even though they are absent in a period of the year. For instance, *R. crisilda* flies from April to November, *S. howqua* only flies from May to October.

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Table 7. Individual density of indicator species for the natural forest.
Таблица 7. Плотность особей видов-индикаторов для естественного леса.

Indicator species	Month							
	IV	V	VI	VII	VIII	IX	X	XI
Ragadia crisilda	1.0	3.2	0.2	—	2.9	1.2	3.0	0.8
Neope muirheadi	0.2	04	2.2	—	0.3	0.5	0.2	—
Stichophthalma howqua	—	0.1	6.4	1.6	0.6	0.1	0.1	—

Note: Individual number/observation/100–m transect.
Примечание: Количество особей/наблюдений/на 100 м трансекты.

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